Introducing an Intelligent Transportation System Decision Support Model for the Highways in Iran Based on Fuzzy Logic

Milad Ghanbari, Abozar Godarzi Mehr, Hamid Nehzat

***Abstract*—The significance of inner and inter-city highways in terms of security, environmental pollution, and the capacity and density of the lanes has led to implementation of intelligent transportation infrastructure. The use of Intelligent Transportation Systems (ITS) economizes on costs and time. ITS enjoying high technology in information processing, communications, electronic controll establish a proper and safe relationship between man, vehicles, and roads. This paper aimed to introduce a Decision Support System (DSS) in order to select the kind of intelligent transportation system for the highways in Iran. The research taking advantage of the ideas of some experts in the field of traffic and transportation performed fuzzy logic (FL) model in MATLAB software. The validity of the model was studied and confirmed in a case study of two highways.**

***Index Terms*—fuzzy logic, traffic engineering, intelligent transportation system, highway capacity, decision support system.**

I. INTRODUCTION

Highways are in the spotlight for city traffic and transportation managers in developed and developing countries. In fact, highways are considered as one of the most important communication and transportation lines. Due to a considerable increase in vehicle ownership and a high demand for urban and inter city travel, highways across the globe experience high density everyday [1]. One of the solutions to deal with such density and the consequent problems is to build new infrastructure to increase the capacity of roads which does not seem to be proper owing to high economic and environmental costs and shortage of space in urban areas. Therefore, it seems necessary to come up with a solution to improve the current systems effectively and efficiently. It is imperative to have a new generation of vehicles and intelligent highways which can communicate with each other. An intelligent highway is an intelligent transportation system in which vehicles and highways send and receive information to each other through communication systems [2], [3]. Integration of decision making management and planning is the most important action to take in management of urban and inter city roads. By the same token, prioritizing intelligent transportation systems in mega cities based on the most accident-prone areas could be one of the significant steps.

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When designing and building highways, traffic managers suffer some confusion in the selection, design, and building the optimal level of the ITS due to limitations of time, finance, construction, environment, access to high technology, security, precision, skills, and etc. This paper was an attempt to provide a decision making support model for the selection of the optimal intelligent transportation system for the main urban and inter city roads specifically highways based on fuzzy logic (FL).

II. REVIEW OF LITERATURE

The precedence of intelligent transportation system in Iran as well as other countries goes back to the use of traffic lights in inner-city junctions. The first timed traffic lights were use almost fifty years ago. However, academic research on traffic and roads in Iran began approximately fourty three years ago [4]. The automatic traffic lights control systems which electronically adjusted the time of the lights gradually substituted the manual ones which are still used in a lot of major cities in Iran. These lights have the same timing for all day long unless a police officer present at the junction changes it. With the advances in telecommunications and electronics, using ITS to deal with traffic problems has been a main policy in modern countries such as the USA and Japan since 1980 [5]. A research by university of Florida [6] showed that an automatic highway system is made by comprehensive communication between the road and intelligent vehicles. In fact, an intelligent transportation system organizes traffic efficiently [7], [8], reduces speed changes [9], monitors insecure vehicles [10], maximizes the capacity of the highways [11], and minimizes inevitable densities [12]. A recent research recognized precise prediction of the traffic as the basis of intelligent transportation in city traffic control. To do so, it focused on the nonlinear relationship of traffic and then introduced an algorithm based on time–location relationship to make predictions [13]. Decision support systems have been used in transportation network planning for a long time [14], [15]. A case study of the comprehensive transportation decision making support system in Turkey is one of such studies which considered the feasibility study of road capacity development along with the predicted growth of traffic and to improve health and environment emloyed the strategy of planning that suited the growth of traffic [16]. It should be mentioned that the design and planning of such decision support systems could also be based on GIS or Computing-based Grid [17], [18] and [19]. Traffic situation, environment (weather), sight, and risks of accidents are considered to be the most important factors determining speed limit. Intelligent transportation systems are somehow one of the ways to control speed limit which enjoys fuzzy

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logic, genetic algorithm (GA) and Software architecture [20], [21] and [22]. Attention in all studies in the field of transportation is given to the uncontrolled growth of traffic which means concerns about the limited capacity of roads as well as health and environmental hazard. Hence, the design of traffic management systems requires consideration of sustainable development [23], [24]. The review of literature demonstrates that variables such as the kind of road, economy, security, the importance of the line, as well as time are of great significance in the study of ITS. Recently, the use of decision support systems in ITS have received more attention. The use of fuzzy logic as a decision making tool in urban highways seems to be efficient.

III. ITS LEVELS

The most important functions and services offered by ITS include A:Managing accidents and rescue service, B:Giving information to drivers and passengers publically, C:Managing traffic and monitoring the vehicles on the road, D:Increasing the capacity of the lines. Intelligent transportation systems can be categorized into different levels according to the costs, execution time, and precision. First, the systems and tools in highways are briefly introduced and later for the purpose of modelling, they are categorized into four groups according to the mentioned criteria. Traffic lights, electronic signs, sensors, speedometers, and etc are the tools in intelligent transportation systems (see figure 1). In this paper, intelligent transportation systems were categorized into four levels by means of a questionaire, and interviews with experts and scholars in the field of traffic and transportation engineering which are presented in table I. The levels of the system are accumulative meaning that each higher level includes the systems of the lower level. In other words, level two enjoys its own technologies as well as the ones in level one. Level three also includes level two and one. The fourth intelligent level includes all the modern intelligent technologies present in all four levels. The output variable of the decision support system in this research is the intelligent level.

Fig. 1. The urban and inter city intelligent transportation systems

Remote traffic microwave sensors (RTMS) collect information about vehicles and traffic which include the presence, height, length, speed, and number of the vehicles, the density of the moving traffic, the length of the line of the vehicles as well as recognition of traffic cessation. The system of weighing in motion (WIM) is one of the most effective ways of controlling the weight of vehicles moving on a certain road. This system can control the traffic of vehicles with illegal load which cause damages to the buildings on the road such as bridges, tunnels and the pavement.

Table I. Classification of intelligent transportation systems

NO.	Transportation system	Tools & Technologies
1	Intelligent 1	1-Traffic lights intelligent making tekhnologies 2-Meteorological sensors 3-RFID stickers
2	Intelligent 2	1-Intelligent 1 2-Recognition and recording system of plate numbers 3-Speed cameras 4-Electronic equipment 5-GPS
3	Intelligent 3	1-Intelligent 2 2-Road side radio sensors 3-Computer data center 4-Electronic Toll Collection (ETC) 5-Remote Traffic Microwave Sensor (RTMS) 6-Automatic radio information 7-Closed-circuit television (CCTV)
4	Intelligent 4	1-Intelligent 3 2-Light fibers 3-Intelligent vehicles 4-Electronic Toll Collection (ETC) 5-Special linings 6-Weigh in motion (WIM) 7-Variable Message Sign (VMS) 8-Accident intelligent detection (AID) 9-Advanced Traveler Information System (ATIS)

IV. FUZZY LOGIC MODELLING

According to the operationalized levels defined for intelligent transportation in table one input variables are considered as the input for the fuzzy logic model. The input variables of the model include kind of road (highway and freeway), lines number (with two, three, or four or more lanes), significance of the road in terms of security, accidents, density, transit, and any justifiable social, political, or economical factor (usual, significant, special), the level of the financial credit allocated for the project (low, average, high), and the amount of time considered for implementation the system in question (low, average, high). Figure 2 demonstrate the input and output variables of the fuzzy logic model.

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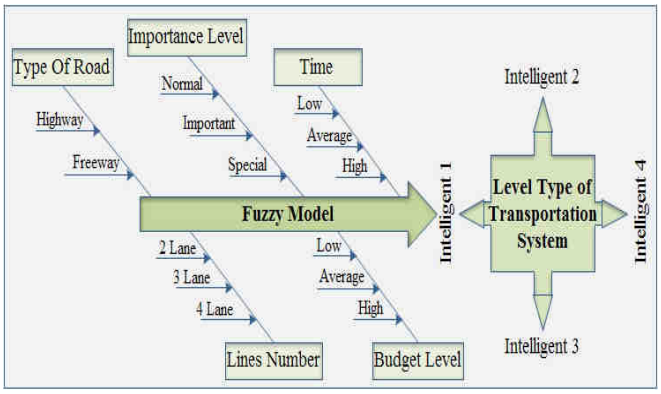

Fig. 2. Inputs and output of the fuzzy logic model

The parameters of time and costs are relative meaning that they are relatively defined according to the length of the highway and the available budget and time. The costs and time of implementing intelligent transportation infrastructure are very high. Therefore, their precise estimation is really difficult in this model as they depend on the number of necessary intelligent devices such as cameras, signs and sensors, as well as the distance between the network and the lines connecting between the data computer center and light fibers, and etc. All this somehow depends on the length of the highway. The structure of Mamadani model is used in the fuzzy logic model presented. The membership functions of three types of the variables are shown in figure 3. Traffic and transportation experts' ideas and judgments were used to define the membership functions of the variables and fuzzy rules by means of a questionaire and an interview. Having analyzed the experts' ideas, fourty five fuzzy rules were set for the model.

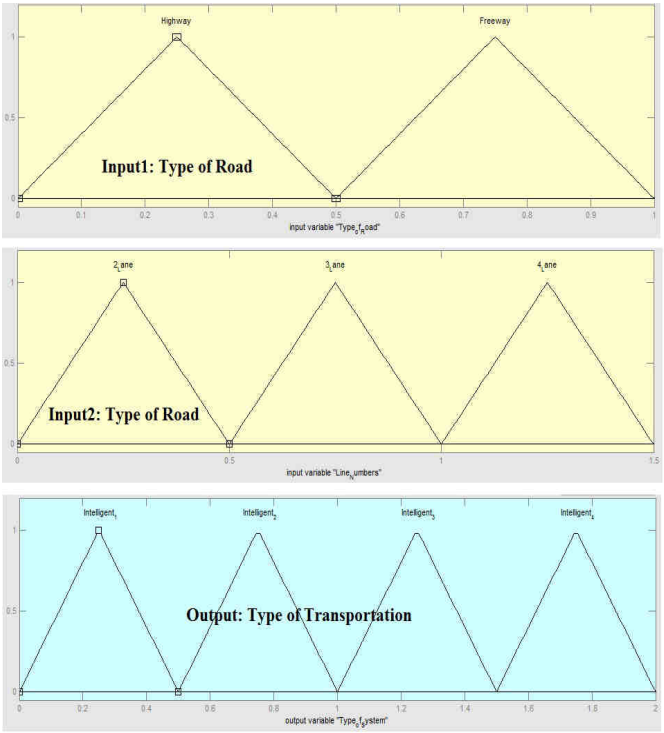

Fig. 3. The membership functions of three types of the variables

To validate the model, two highways, Hemmat and Azadegan, in Tehran were studied. Hemmat highway, eighteen kilometers long, has four lanes and connects the west of the city to its east. The intelligent system used in this highway is of the second level. Azadegan highway, 36.4 kilometers long, also enjoys four lanes, and is so significant in terms of traffic. The intelligent system here is of the third level. The specifications of the two highways were put in the created fuzzy decision model which is briefly demonstrated in table II. As you can see, the results of the fuzzy model agreed with the intelligent systems in the mentioned highways.

Table II. The validation results of fuzzy model for case studies

Case Study	Hemmat Highway	Azadegan Highway
Type of Road	Highway	Highway
Lines Number	4_Lane	4_Lane
Importance Level	Important	Special
Budget	Average	High
Time	Average	High
Fuzzy_Transportation System	Intelligent_2	Intelligent_3
Existing condition	Intelligent_2	Intelligent_3

V. CONCLUSION

The plight of road traffic in terms of security and relief, and high number of road accidents have drawn the attention of modern countries to intelligent transportation systems (ITS) so as to increase the capacity of communications. Hence, taking the advantages of ITS in Iran where there are more road accidents annually seems to be inevitable. ITS could be defined, designed, and executed in different levels each of which requires different costs considering the required equipment and the time needed to operationalize. To implement such vital infrastructure in urban and inter city areas, there is need for feasibility studies to choose the optimal intelligent transportation system. In this research, to create a decision support system (DSM) in order to select an intelligent transportation system based on the optimal costs, using the traffic experts' ideas, fuzzy logic (FL) was applied. The created model was based on Mamadani structure with five input variables including the kind of highway, the number of lanes, costs, time, and the significance of the road, and one output variable i.e the kind of ITS which were put in MATLAB software. Experts' ideas were used to define fuzzy rules. To validate the model, two highways in Tehran were studied. The results of the case studies approved of the potential of the model. The created decision support system could be used in initial design and implementation of intelligent transportation urban and inter city lines by traffic consultants, contractors, and high ranking officials.

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